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1984 SUMMARY OF NMC OPERATIONAL GLOBAL ANALYSIS

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I. Introduction

Researchers throughout the meteorological community use the NMC global analyses for a wide variety of studies. In order to correctly interpret the results of such studies, the researchers should know how these analyses were produced. The fundamental concepts of the optimum interpolation analysis procedure now used for all our global analyses is described in Dey and Morone (1985). However, details of the application of this analysis procedure (as well as others that have been used at NMC) have, in the past, often been difficult to find and sometimes simply did not exist. Yet these details can at times be crucial to a complete understanding of the analysis system. This brief note is intended to be the first of an annual series, permanently documenting the evolution of global analysis procedures used at NMC in more detail than can be found in the formal literature.

Section II describes the changes we made to our operational analysis procedures during 1984. Various problems that significantly affected our global analyses during 1984 are recounted in the final section.

II. Changes Made During 1984

Three distinct global analyses are run at NMC every 12 hours: the RADAT analysis (1+20 data cutoff), the GAFS--Global Analysis/Forecast System--analysis (3+45 data cutoff), and the GDAS--Global Data Assimilation System--analyses (9+30 data cutoff for data centered on 0000 GMT and 1200 GMT, 10+30 data cutoff for data centered on 0600GMT and 1800 GMT). At the beginning of 1984, the RADAT and GDAS analyses were based on the principles of optimum interpolation (OI), while the Hough analysis was used in the GAFS. Two major accomplishments during 1984 were the completion of the software conversion of the GDAS to the CYBER 205 on March 22, and the replacement of the Hough analysis by an OI analysis in the GAFS on July 27. In addition, we made a number of significant modifications to our analysis techniques. By the end of 1984, all three global analyses were based on OI, and therefore were almost indentical with respect to basic analysis methodology. However, while the GAFS and GDAS OI codes are virtually identical, both differ substantially from the RADAT OI, which remains as it was early in 1983.

A. Implementation of 1200 GMT, 22 March 1984

This involved the most complex software modification of all the implementations made during 1984. It marked the completion of the conversion of the GDAS to the CYBER 205. There were basically four changes made at this time.

1. The GDAS OI was first converted to the CYBER 205 in September, 1983. At that time, several non-analysis parts of the GDAS remained on the IBM 360/195 in order to meet the conversion deadline. In this implemention, all remaining parts of the GDAS, except the data preprocessor, were converted to the CYBER 205. The result was a faster, more efficient product.
2. Previously, a separate analysis of mean sea-level and surface-pressure reports was run on the IBM 360/195 to provide the surface pressure field which defined the sigma coordinate of the prediction model. Under the revised scheme, the surface analysis is no longer done. Rather, the surface-pressure field is calculated from the analyzed heights and the prediction model's terrain. The surface-pressure field calculated in this way is more in balance with the upper-air analysis. As a result, the changes made to the analyzed surface-pressure field by the nonlinear normal-mode initialization were

reduced to about half their previous values.

3. The separate surface analysis also produced a 1000mb height field that was used to anchor the TIROS soundings. The elimination of the surface analysis necessitated a change in this procedure. Now, TIROS reports are first temporarily anchored to the first-guess 1000mb height field in order to check for gross errors. Following the 1000mb height and wind analyses, the TIROS reports are re-anchored, and are then buddy-checked with the RAOB height data. The TIROS reports anchored in this way are more consistent with the 1000mb analysis.

4. The form of the horizontal height autocorreclation function ($\mu_{h_i h_j}$) equatorward of 70° can be written

$$\mu_{h_i h_j} = e^{-K_h R^2 \left[(\lambda_i - \lambda_j)^2 \cos^2 \hat{\phi} + (\phi_i - \phi_j)^2 \right]} ,$$

where λ is longitude, ϕ is latitude, R is the earth's radius, and K_h is a constant. Previously , $\hat{\phi}$ was defined to be ($\phi_i + \phi_j$)/2. In the new form, $\hat{\phi}$ is defined to be the latitude of the analysis point. As such, it is not differentiated when deriving the other correlation functions from $\mu_{h_i h_j}$.

B. Implementation of 1200 GMT, 18 April 1984

Three refinements were made to the GDAS OI at this time.

1. The buddy check was rearranged to permit the use of observed wind residuals above 925mb in the 1000mb analysis of height and wind. These winds had been inadvertently excluded in the March 22 implementation.

2. Previously, all off-level wind reports were grouped with those at the next lower mandatory pressure for buddy-checking.

This change to the buddy check vertically groups all off-level wind reports with those at the closest mandatory pressure level. This resulted in the rejection of more off-level wind data by the buddy check.

3. The data selection procedure was changed to provide a better mix of observed height and wind residuals at and above 100mb. The effect was to reduce the mean height error of the analysis at these levels.

C. Implementations of 1200 GMT, 27 July 1984

Since 1974, the Hough-Function Analysis had been used in the GAFS. In this landmark implementation, the Hough-Function Analysis was replaced by a version of OI. In most repects, this OI was the same as the version that was implemented in the GDAS on March 22 and revised on April 18. However, there were a few differences:

1. The vertical profile of the forecast-error standard deviation (FESD) was restricted and its horizontal resolution was limited to 10 waves. Unrestricted vertical profiles and 30-wave resolution of the forecast-error standard deviations were being used in the GDAS OI at this time. This change addressed two problems: FESD values that decreased too rapidly near the the ground had been causing the analyzed low-level winds to be too strong in the Indian Ocean, while 30-wave resolution allowed the horizontal gradients of the FESD to be too strong.
2. The first guess was updated in pressure coordinates, then the analyzed fields were expanded from 30 to 40 waves and interpolated to the sigma coordinate of the GAFS prediction model. In the GDAS, the analyzed corrections to the first guess are interpolated vertically to sigma

coordinates, where the updating is done. This change was necessary because the GDAS prediction model, which provides the first guess for the GAFS OI, has 30-wave resolution, whereas the GAFS prediction model has 40-wave resolution.

3. The highest sigma layer of the global spectral prediction model used in the GDAS is never updated by the GDAS OI. Because of this the top sigma layer becomes somewhat decoupled from the rest of the model atmosphere. When interpolating the 6-hour GDAS forecast from the sigma coordinate of the prediction model to mandatory pressure levels, the decoupled layer leads to unbalanced mass and wind fields at 50mb and, to a lesser extent, at 70mb. In this change, the top sigma layer was not used in creating the pressure-level first-guess fields. The result is a better balance between the first-guess mass and wind fields at 50mb and 70mb.
4. Upper-air bogus height data were used, except in the vicinity of TIROS reports. Upper-air bogus data are not used in the GDAS.

D. <u>Implementation of 1200 GMT, 6 September 1984</u>

The first and third improvements made on July 27 were implemented in the GDAS OI as part of a group of changes. The other modifications were:

1. The selection procedure was altered to improve the vertical consistency of the analysis. This was done by insuring that when sounding data are available, some data from a given sounding are selected for each level of the analysis at the appropriate grid point.
2. The tropical wind analyses (10°N to 10°S) were changed from bivarate to unvariate. This permits the analysis of divergent wind corrections.
3. The adiabatic nonlinear normal-mode initialization was replaced with a diabatic procedure.

E. Implementation of 1200 GMT, 20 September 1984

At this time, improvements 1 and 2 listed for the September 6 implementation were implemented in the GAFS OI as well. The diabatic initialization was omitted because the required 40-wave version was not ready. With this implementation, the global OI analyses used in the GAFS and GDAS were, for all pratical purposes, indentical.

F. Implementation of 1200 GMT, 3 October, 1984

PIBAL reports with less than four levels of information were being erroneously selected twice for use in the analysis, leading to ill-conditioned matrix problems. This did not affect the analysis results, however, because each ill-conditioned problem was automatically corrected by removing the duplicate observation. This oversight was introduced in the GDAS on September 6, and in the GAFS OI on September 20. The correction, made on October 3, prevented these observations from being selected twice in the first place.

G. Change of 0000 GMT, 5 December, 1984

At this time, the data cutoff for the 0000 GMT GDAS was moved from 0930 GMT to 0800 GMT. This was done to accommodate the testing of an 18-layer version of the 40-wave global spectral prediction model which contains GFDL E2 physics. The 18-layer E2 physics version was then run once daily from the 0000 GMT GDAS analysis to ascertain what improvements could be expected in the medium-range forecast products, and also to determine if the 8 + 00 data cutoff would allow sufficient time for completion of the 10-day forecast.

III. Problems Encountered During 1984

A. Use of Backup Computer Codes

In the past, the backup computer used at NMC was the same as the primary computer, so the question of backup computer codes did not arise. Since our acquisition of just one CYBER 205, however, the backup computer has been a much less powerful IBM 360/195 or NAS 9040. This means our backup computer codes are considerably different from the primary operational versions.

At the beginning of 1984, only the GDAS OI was running on the CYBER 205, and it had few differences in analysis methodology from its backup. However, none of the improvements described in section II were made to the backup codes. Now, the GDAS OI run on the 205 is substantially different from its backup (which has not changed). Even more importantly, the backup for the GAFS OI is the previously operational Hough Analysis. When the CYBER 205 is unavailable and the backup codes are run, substantial differences in the details of the analysis can occur from what would have been produced by the CYBER 205 version. Table 1 gives the times when the CYBER 205 was unavailable for the GAFS OI and the Hough analysis was run instead. This information was available only for the months of August, September, and October. In the future, we hope to have complete tables for both the GAFS OI and the GDAS OI.

B. Use of a Non-standard First Guess

Normally, the first guess for all global analyses is a 6-hour forecast from the GDAS OI. This forecast is produced with a 30-wave, 12-layer version of the NMC Global Spectral Prediction Model. Occasionally, the GDAS will not be completed in time to provide this first guess. In these cases, an alternative first guess must be used. The first choice for an alternate is the 12-hour forecast from the GAFS OI. This is a 40-wave, 12-layer version of the NMC Global Spectral Prediction Model. In the rare cases when this forecast is also unavailable, the most recent analysis is used.

The effect on the ensuing analysis of a 12-hour, 40-wave prediction rather than a 6-hour, 30-wave prediction is not large. The effect of using a previous analysis would be somewhat more noticeable, although it seldom occurs. Nevertheless, those days for which the normal first guess was unavailable are listed in Table 2 for the sake of completeness.

C. Miscellaneous Problems

In an operational environment as complicated as that at NMC, inadvertant changes are occasionally introduced that adversely affect the global analyses. During 1984, two such cases arose. They are described in this section.

1. Episode of 16-24 July

All TIROS data were inadvertently deleted from the GDAS, begining at 1200 GMT, 16 July through 0600 GMT, 24 July. Due to the absence of TIROS data during this period, tropical surface pressures become abnormally low and subtropical pressure gradients unusually strong. The GDAS returned to normal 24 hours after the TIROS data were reintroduced. The reason for this response of the GDAS to the absence of TIROS data was traced to a lack of controls on the evolution of forecast-error standard deviations by the GDAS OI. Such controls were implemented in the GAFS OI on July 27. The same controls were implemented in the GDAS OI on September 6.

2. Episode of 13-26 November

At 0000 GMT on 13 November, a disk pack containing the GDAS OI code failed. When it was repaired, an old version of the GDAS OI was placed on the disk by mistake. This error was not discovered until 1200 GMT, 26 November, when the correct version was restored. The old version of the analysis used from November 13 to November 26 contained errors that had not been corrected.

The result was a gradual deterioration of the analyses between 30°N and 30°S until the correct version of the GDAS was restored.

Acknowledgement: Some of the information presented here was compiled from the NMC Monthly Performance Summary edited by Dr. John Ward. We gratefully acknowledge John's permission to use the information in this note.

Reference

Dey, C. H. and L. L. Morone. Evolution of the National Meteorological Center Global Data Assimilation System: January, 1982 - December, 1983. To be published in the February, 1985 issue of the Monthly Weather Review.

Table 1. Time, Day for which the CYBER 205 was unavailable for the GAFS OI and the backup Hough Analysis was run on the front-end computer.

August, 1984:	0000 GMT, 2
	1200 GMT, 3
	0000 GMT, 10
	1200 GMT, 16
	1200 GMT, 18
	1200 GMT, 19
September, 1984:	0000 GMT, 1
	0000 GMT, 2
	0000 GMT, 8
	1200 GMT, 16
	1200 GMT, 25
	1200 GMT, 28
October, 1984:	0000 GMT, 2
	0000 GMT, 3
	0000 GMT, 6

Table 2. Time, Day for which the normal 6-hour forecast from the GDAS was unavailable for use as a first guess. Unless otherwise indicated, the first guess was provided by the 12-hour GAFS prediction.

January, 1984:	0000 GMT, 1
	0000 GMT, 2
	0000 GMT, 5
	1200 GMT, 5
	0000 GMT, 10
	0000 GMT, 11
	1200 GMT, 11
	1200 GMT, 15
	0000 GMT, 19
	1200 GMT, 19
February, 1984:	0000 GMT, 4
	0000 GMT, 10
	1200 GMT, 10
March, 1984:	0000 GMT, 9
	1200 GMT, 16
	0000 GMT, 17
	1200 GMT, 17
	1200 GMT, 21
	0000 GMT, 30
	0000 GMT, 31
April, 1984:	0000 GMT, 2
	1200 GMT, 3
	1200 GMT, 4
	0000 GMT, 11
	1200 GMT, 17
	1200 GMT, 18
	1200 GMT, 23
	0000 GMT, 24
May, 1984:	0000 GMT, 11
	1200 GMT, 11
	1200 GMT, 19
	1200 GMT, 20
June, 1984:	0000 GMT, 15
	1200 GMT, 21
	1200 GMT, 22
July, 1984:	0000 GMT, 12
	1200 GMT, 23
August, 1984:	1200 GMT, 8
	0000 GMT, 9
	1200 GMT, 10
	1200 GMT, 26
September, 1984:	0000 GMT, 3
	1200 GMT, 6
	1200 GMT, 7
	1200 GMT, 8
October, 1984:	1200 GMT, 15
	0000 GMT, 16
	0000 GMT, 19
	1200 GMT, 21
	0000 GMT, 22
	0000 GMT, 31
November, 1984	1200 GMT, 11
	0000 GMT, 13
December, 1984:	1200 GMT, 11
	1200 GMT, 12
	0000 GMT, 13
	1200 GMT, 15
	1200 GMT, 26
	1200 GMT, 27
	1200 GMT, 28